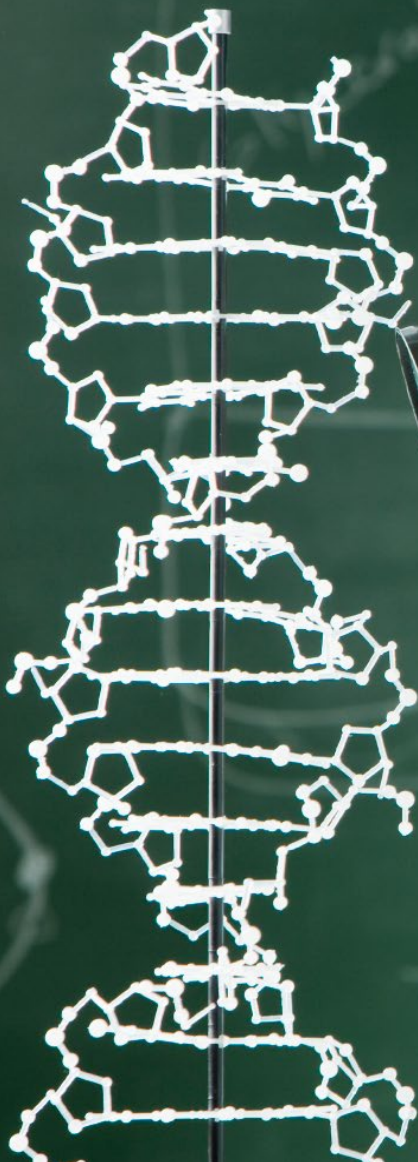


A Guide to Gene Therapy






Thank you for including us on your journey! Most likely you have a need for this toolkit: A Guide to Gene Therapy because you or a loved one has a rare genetic disease. As you prepare to use the tools in this kit, we want you to know that you are not alone. We are in this together. It is our hope that the personal stories, resources, tips, and suggestions for self-reflection in this guide will make the road to advocacy for your rare disease more manageable.


We know, all too well, that a lack of information and support for people living with RARE diseases can lead to feelings of dis-ease. Please know, it's not just you—feeling depressed, anxious, and isolated are common conditions in the RARE community. Fortunately, RARE advocates see these challenges as opportunities to take control back from their disease by filling the void with support, knowledge, and change to proactive next steps.

While we believe you will benefit from reading all of the material in this toolkit, we don't want to overwhelm you. We've included a table of contents to make it convenient for you to find the information you are most interested in at this time. ■

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 *Paper and pen indicate an interactive exercise*

 *Exclamation point indicates a fun fact*

Intro to Gene Therapy: Gene Pool

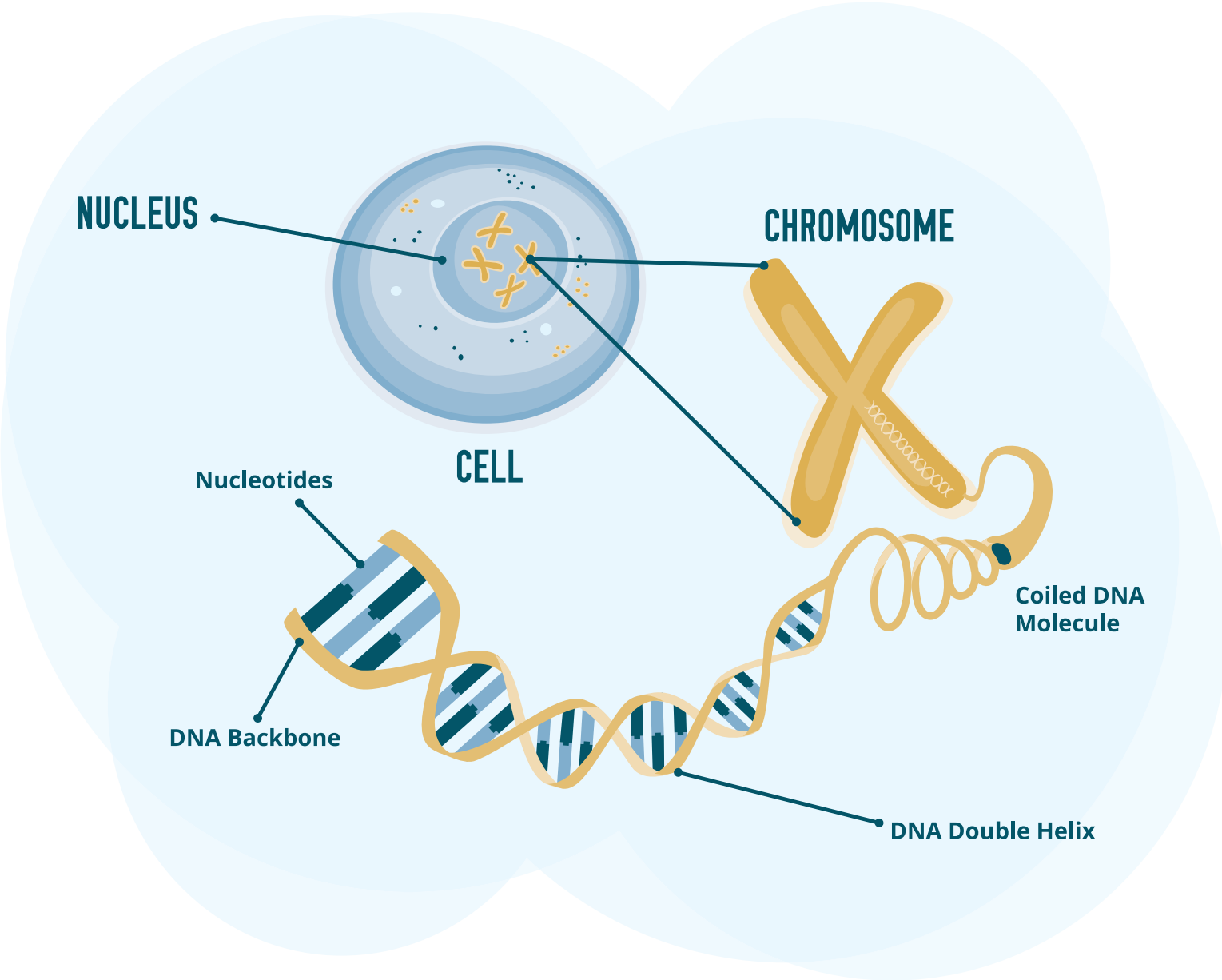
Come On In, The Water Is Fine!

Within the human body thousands of molecules act together to:

- Turn food into energy for cells
- Make the nerves transmit signals from the body to the brain and back again
- Take oxygen from inhaling air and moves it to cells
- Perform all the other jobs needed for the body to develop and repair
- To make it easier to zip up tight jeans (We wish!)

Many of these molecules are proteins. Genes provide the instructions (and a tiny “L” shaped, do-it-yourself wrench) necessary for building proteins. When these instructions are incorrect the result may be proteins that do not work, too much of a protein, or too little of a protein. Each of these results can cause many problems within the body.

Many rare disorders are caused by changes in a gene or genes that change proteins in a way that makes them malfunction. Most treatments for diseases and disorders target the proteins. In contrast, gene therapy is targeted at fixing the faulty gene or genes directly and restoring the functional protein. ■



Gene Therapy Interactive

List three things you have heard about gene therapy for the treatment of rare diseases.

1. _____
2. _____
3. _____

The goal of this toolkit is to provide rare patients and caregivers with an overview of gene therapy and why it is being considered as a possible treatment for many rare diseases. To make the content easier to connect with and more engaging there are illustrations, interactive journal prompts, and trivia about genes and jeans.

Topics covered in the toolkit include:

1. An introduction of what gene therapy is
2. A brief history of the development of gene therapies
3. An explanation of how gene therapy works
4. A summary of where gene therapy research is today which includes: current challenges, examples of advances with gene therapy treatments, and what the future might hold



Gene Therapy-101

Attention shoppers! Gene therapy is not a form of “retail therapy” that makes you feel better after you buy a new pair of bootcut jeans. Gene therapy is a scientific approach to directly fixing the change in a gene or genes. There can be different approaches to gene therapy based on what the change in the gene is.

Gene therapy can involve:

- Inserting a normal gene
- Switching a mutated gene for a normal gene
- Changing how often the gene turns on to make a protein or turns off to stop making a protein

Because of groundbreaking research for new methods of gene therapy, it may even be possible to repair a mutated gene by correcting only the harmful change or changes in the gene.

Mother's Hips

If you were paying attention in your high school biology class, the following material about cells will be familiar to you. But, if your attention was otherwise directed on your cute lab partner, here's what you missed.

DNA (deoxyribonucleic acid) holds most of the genetic information for development and for functioning. A gene is a specific region on DNA that codes for RNA (ribonucleic acid). RNA is what often instructs the body to make proteins that it needs.

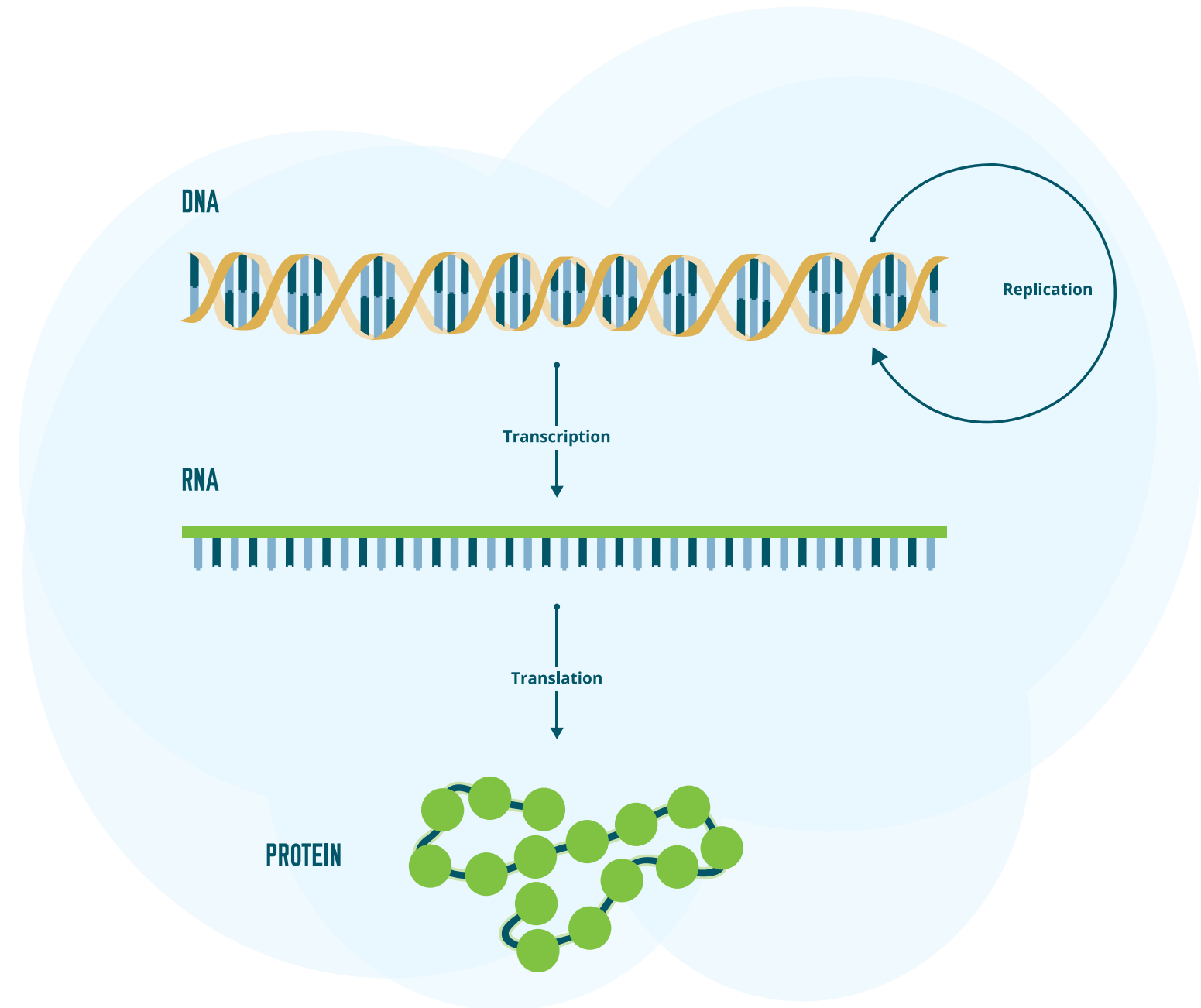
Every cell in the body contains two copies of each gene. Humans inherit one gene from each parent in the form of a chromosome. Chromosomes are tightly wound DNA strands that are found in the nucleus of each cell.

Cheat Sheet Summary:

- Every cell in the body contains 46 chromosomes (23 pairs) within a nucleus, which is separated from the rest of the cell.
- Each chromosome is made of DNA (deoxyribonucleic acid), and a gene is a specific region of the DNA that codes for RNA (ribonucleic acid), which in turn, often codes for a protein.
- The order of the DNA nucleotides in a gene determines the order of the RNA nucleotides, which determines the order of the amino acids in the protein.
- We have two copies of each gene, and we inherit one copy from each of our parents. Now we know why some of us have our mother's wide hips or our dad's ample waistline; which means jeans designed for stick figures are not an option.

! FACTOID:

Dogs have 39 pairs of chromosomes and cats have 38 pairs.



Change Agents

A genetic mutation means there has been a change in the sequence of the nucleotides within a gene. This change in sequence can result in a protein that does not work, or too much of a protein, or not enough of a protein. Genetic mutations can be inherited from a parent's genes or they can be de novo, which means the change is new to a person. Likewise, a mutation may be a substitution in the sequence of the DNA or it may involve sections of the DNA being deleted or repeated.

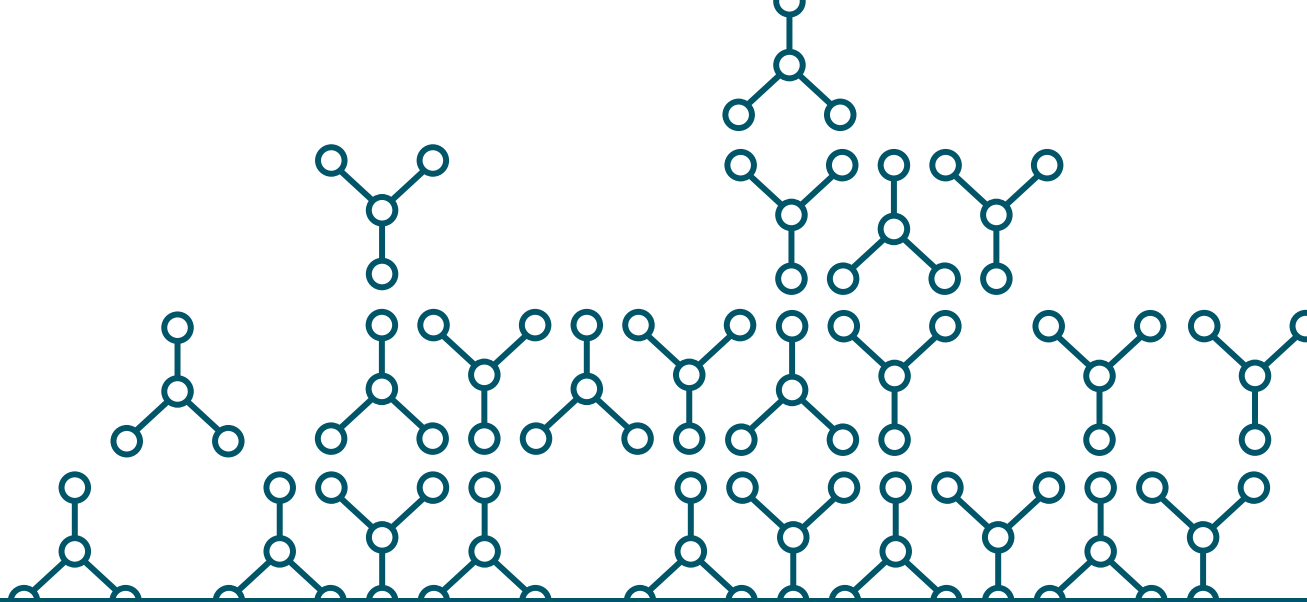
Many times, these changes in the DNA do not lead to an abnormal protein; but there are times when the change causes a problem. If a change in only one copy of the gene causes a disease, the disease is referred to as a dominant disorder. If a disease only results when there are changes in both copies of a gene, the disease is referred to as a recessive disorder.

! FACTOID:

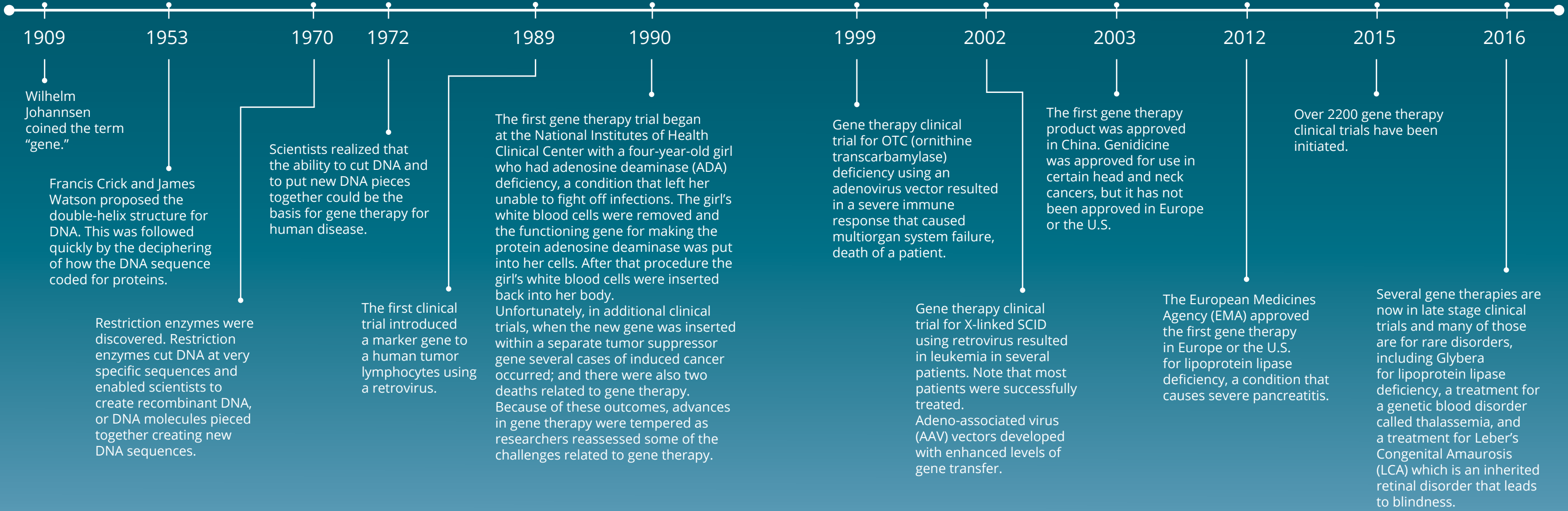
The average person owns seven pairs of jeans, but wears only four!
(Source-Glamourfashion.com)

Brief History of Gene Therapy

The discovery of genes came from many different scientists over many years. Each of them expanded upon the work of scientists who came before them to delve deeper into the concept of genetics. These early scientists understood that traits could be inherited, but they did not visualize genes or have evidence of their existence. It wasn't until the late 19th century and early 20th century that chromosomes and genes were first observed. Throughout the 20th century, scientists made many advances in understanding genes and how they cause many rare disorders. ■



Timeline



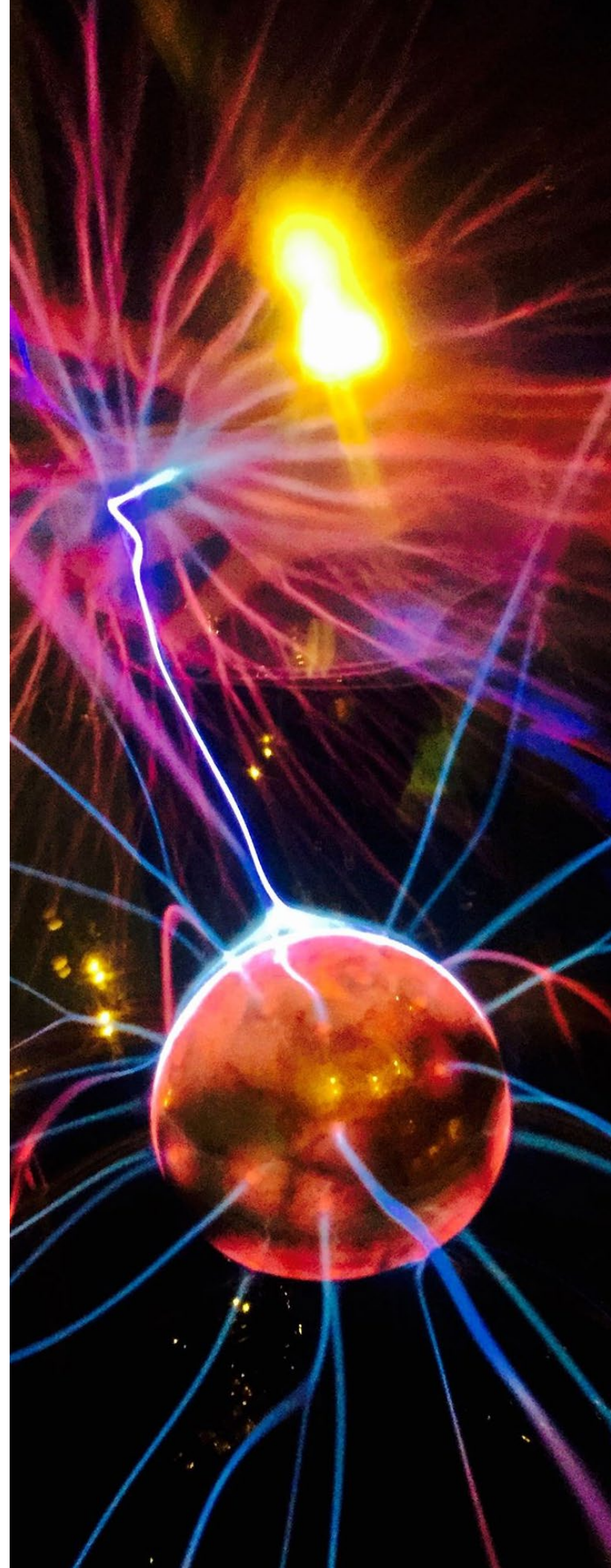
Disorderly Conduct: The Basis for Gene Therapy

Yelling too loudly at your kids soccer game or mowing the lawn before 6:00am may be considered by others disorderly conduct, but it is unlikely that either scenerio is caused by a genetic disorder; and can be most likely be managed with some self-restraint. Genetic disorders, on the other hand, may be helped by gene therapy intervention.

To intervene, researchers need specific information about the cause of a genetic disorder before it can be explored as an experimental treatment. To develop a gene therapy, researchers must:

- First identify the target gene causing the disorder.
- Understand the mechanics of the mutation.
- Know which types of cells in the body are abnormal because of the mutation.

Once this information is understood about a disorder, a researcher then moves to uncovering the best way to deliver a normal gene or to repair the mutated gene in the affected cells. ■



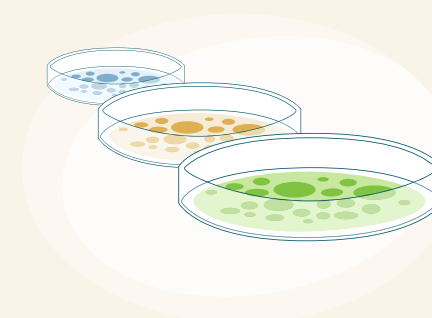
GLOBAL GENES *Pharma-to-Table Café*

Seasonal veggies and fresh dairy products from Old Mc Donald's farm down the road (give or take 500 miles) are popular offerings on farm-to-table restaurant menus. Spoiler alert! Summer squash, fresh bingleberries, or double-clotted butter are not on the Global Genes' Pharma-to-Table Café menu. What you will find are, potentially, life changing "ingredients" simmering in laboratory petri dishes that are advancing medical discoveries in gene therapy.

Two large orders of cells to go!

Gene therapy can be done with somatic cells or germline cells. There are two ways to deliver gene therapy. Each delivery approach has its advantages. When the gene therapy is administered ex vivo, immune reactions from the delivery method are minimized. The cells can also be tested to ensure that the gene has inserted into the genome. However, ex vivo gene therapy is limited to cells that can be safely removed from the body, such as blood cells.

Gene Petri Dish Menu & Delivery Options



Types of gene therapy

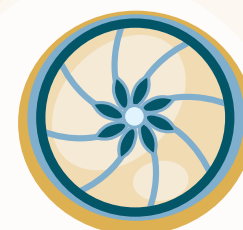
In vivo

Gene therapy can be administered to cells within the body in vivo gene therapy.

Ex vivo

Gene therapy can be administered to cells that have been isolated from the body and are reintroduced after the gene therapy occurs, ex vivo gene therapy.

Entrees



Germline Cells

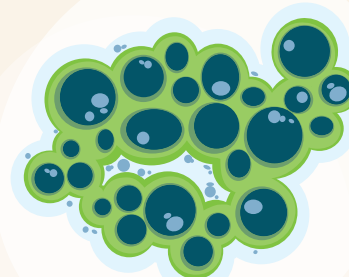
1. Germline Cells

Germline cells are the body's reproductive cells– sperm and eggs (with rye toast).

Petri Dish Review

- Any change made to germline cells will be passed to future generations.
- The creation of "designer babies" whose genetic makeup has been pre-selected to eliminate a particular defect or to insure a particular gene is present in a baby is one of many ethical concerns researchers have about germaline cells; and also why researchers are not pursuing this approach.

Availability: Due to ethical considerations germline cells are not available for gene therapy (dine-in or take-out).



Somatic Cells

2. Somatic Cells

Somatic cells are the non-reproductive cells throughout the rest of the body.

Petri Dish Review

Somatic cells are the approach being pursued by researchers for gene therapy.

Availability: A savory dish of somatic cells can be delivered in vivo or ex vivo.

Gene Therapy Delivery Options



For gene therapy to be effective, the new gene must complete several steps:

1. It must be delivered into the correct, targeted cells.
2. The gene must be appropriately incorporated into the cell's existing genetic code or remain whole in the nucleus.
3. Finally, the new or fixed gene must "turn on" so that it produces a normal protein or it knocks down production of a bad protein.

There are several options to deliver genes strands into the body. Each has its own benefits and potential complications. Researchers are currently studying each delivery method to continue to improve the effectiveness of gene therapy.



3. Adenovirus
The virus that causes the common cold is a type of adenovirus.



4. Herpes Simplex Virus
Viruses that cause cold sores are herpes simplex viruses.

Delivery Option 1: Viruses

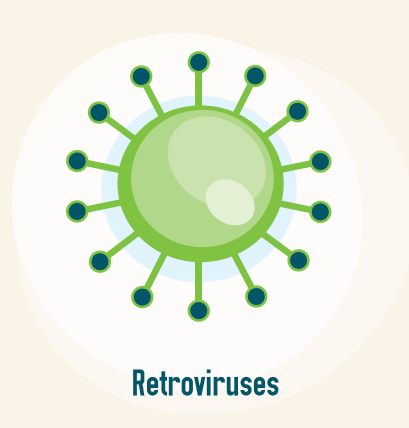
Today's lunch special includes a petri dish of fresh viruses! Researchers have borrowed a process from nature to effectively achieve each of the steps of gene therapy: infections by a virus.

A virus makes more viruses by injecting its genetic material into the cells it infects. Getting genetic material into a cell is the ultimate goal of gene therapy. For this reason and because viral delivery systems are the most effective right now, most clinical and research efforts have focused on using viruses to deliver gene therapy.

When viruses are used as a way to deliver gene therapy to cells, they are engineered so the viruses do not cause a disease and the genetic material they insert into cells includes the new DNA to replace or repair the defective gene. Researchers have used several different types of viruses as vehicles to deliver experimental gene therapies. Some of those viruses are listed here.



1. Adeno-Associated Virus
Harmless viruses that do not cause disease.



2. Retroviruses
Such as human immunodeficiency virus or HIV.

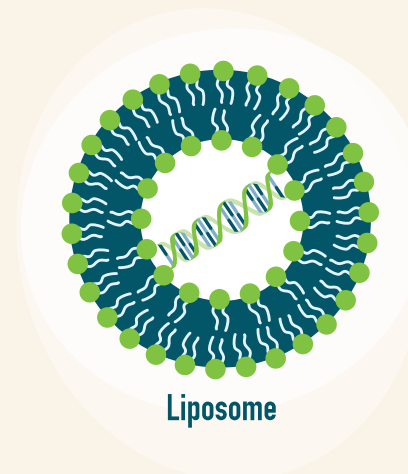
Delivery Option 2: Non-viral

Researchers have also experimented with other ways to deliver the DNA to cells. One approach is simply injecting DNA not enclosed within anything, or naked DNA. To help the DNA get into the nucleus of the target cells, researchers may use a method called electroporation, where electricity is applied to the cell. This causes small openings to be created in the cell's membranes, including the membrane of the nucleus, allowing the DNA to get in.



1. Naked DNA
 - This DNA most often takes the form of a small circle and is called a plasmid.
 - Bacteria use plasmids to exchange DNA, so it also is a method borrowed from nature by researchers.
 - A plasmid is separate from the cell's chromosomes and can be activated and replicated separately.

Another approach to delivering DNA is surrounding the DNA with a small membrane of its own, which is called a liposome.



2. Liposome
 - The liposome has a similar make-up to the cell membrane, so it can fuse with it and help the DNA enter the target cells.

A third non-viral approach that has been an area of intense focus by researchers is using nanoparticles to deliver DNA. A nanoparticle is something that is smaller than 1 micrometer, but many of the nanoparticles being explored for gene therapy are smaller than 400 nanometers, or very, very small.

3. Nanoparticle
 - These particles are so small that they can simply slip through the pores in the cell membrane to deliver the DNA. ■



Taking Aim: Benefits and Expectations of Gene Therapy

The potential benefits of gene therapy are broad reaching. Like an expert archer poised to hit a bull's-eye, researchers around the world are taking aim at minimizing the proliferation of rare diseases via gene therapy. Gene therapy goes further than just treating some of the symptoms of the disorder. It targets the abnormal gene(s), which in-turn treats the underlying cause of the disorder. Also, because gene therapy targets only the abnormal gene(s), it has the potential to eliminate side effects resulting from "off target" effects, or effects a drug or other treatment may have on other functions in the body.

Because the new genes integrate into the cell's genome or are specifically designed to resist being destroyed, there is the potential for a one-time administration or for very infrequent administration of the treatment. Ultimately, gene therapy has the potential to be the closest researchers will get to hit the target that leads to a cure for rare disorders. ■



FACTOID:

**On an annual basis
genealogy websites get over
108 million visits a year.**

(Source-Geanealogyintime.com)



Road Less Traveled: Current Challenges

Size Matters!

Size matters when it comes to the drug development pathway and the field of gene therapy for rare disorders. The patient populations for rare disorders are small, less than 200,000 in the United States to be classified as a rare disorder. Often, the patient populations are much smaller than that. These small populations make it difficult to find patients for clinical trials, and to therefore demonstrate that the therapy is safe and effective in the clinical trial phase.

Because of the small size of the patient populations, some pharmaceutical companies may be reluctant to invest resources in drug development. Gene therapies also face several unique challenges to what is known about genetic code and current available technology. Like all rare disorder therapeutics, researchers continue to work on ways to defeat the challenges that accompany rare disorders.

"Traits such as intelligence are governed by large groups of genes working together - like a football team made up of players in different positions." DR MICHAEL JOHNSON, IMPERIAL COLLEGE LONDON

High IQ: Understanding How a Rare Disorder Works

For a gene therapy to be successful, a lot of passionate and smart people, must know what gene(s) cause a particular rare disorder. Knowing which gene(s) caused the disorder allows researchers to create a plan for fixing or replacing the genes through gene therapy. It is also important for them to understand where the faulty gene is causing problems within the body.

For many disorders the faulty gene is active in some parts of the body and not active anywhere else; which means the gene therapy only needs to be delivered to certain cells. Gene therapy also faces the challenge of making sure the fix for the faulty gene makes it into the right cells, but not other cells where the fix may cause unnecessary side effects.

Similarly, the timing of when the defective gene needs to be fixed is also important. For some rare disorders, fixing the faulty gene early in the patient's life may be necessary before damage to the body increases and it cannot be fixed. In other rare disorders, it may be possible to fix the faulty gene after it has been active and still fix or reverse any damage to the body.

Party Crashers: Disorders Caused by Many Genes

Some disorders are caused by an error in one gene. Like unruly party crashers, many disorders result from errors within two or more genes. When multiple genes must be fixed, the amount of DNA that has to be put into the delivery mechanism gets bigger. This presents a challenge in packing the larger DNA molecules into a small virus or nanotechnology particle. There is also the possibility that some genes may get too large to fit into a virus or other delivery method.

Recessive Versus Dominant Genes

What has been proven is how a gene acts can make the prospect of gene therapy easier or harder in the listed ways:

- If a gene is recessive a person only needs one working copy
- If a person has two defective copies the rare disorder is present.
- If a gene is dominant one working copy of the gene is not enough.
- If a person has one defective copy the rare disorder is present.

Within gene therapy it is much easier to add one active copy of a gene for a disorder caused by a

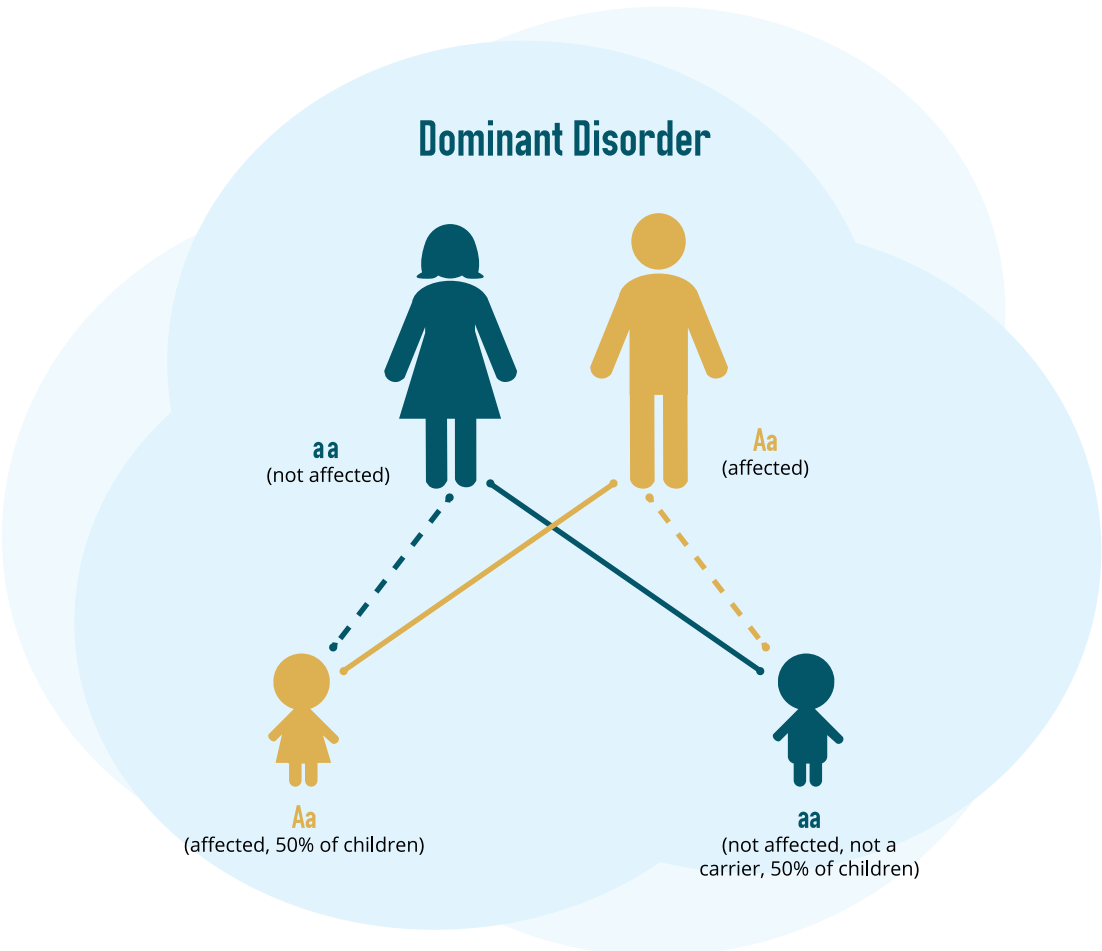
recessive gene than to stop a gene from being active or to “knock down” a gene, for a disorder caused by a dominant gene.

Guard Duty: Immune Response

Difficulties in gene therapy can be related to how the new gene is delivered and how well (or if) the body accepts it. Like a dedicated sentry guarding a castle from intruders, the body’s immune system is the first line of defense against sickness and helps the body protect itself in a number of ways.

While this is normally the desired response, in some situations the immune system can present a problem to the effectiveness of gene therapy especially when a virus is used to deliver the gene. Even though the viruses are changed to not cause the disease they might otherwise cause, the virus may still stimulate the patient’s immune system.

This stimulation can cause inflammation that can hurt the patient. The immune system may also work to kill the virus delivering the gene or kill the cells when the virus delivers the gene. If the immune system is stimulated in these ways, the patient may become sick due to the inflammation or the gene therapy may not work.



Pardon the Disruption

Gene therapy involves inserting a new copy of a gene into the DNA of many cells. Although the chances are low, there is the potential risk that the new copy of the gene is inserted into the DNA in a location that disrupts the way another gene works. In some clinical trials conducted in the late 1990s, gene therapy insertion into a gene that controls the way cells divide led to cancer.

Since then researchers have developed several methods to be sure the gene inserts in a safe place in the genome, and methods allowing more specific targeting are being worked on (see the discussion in this toolkit on gene editing). When the gene therapy is done while the cells are outside the body, the cells can be tested to be sure the genes have integrated into a safe part of the genome.

King’s Ransom: The Cost of Gene Therapy Products

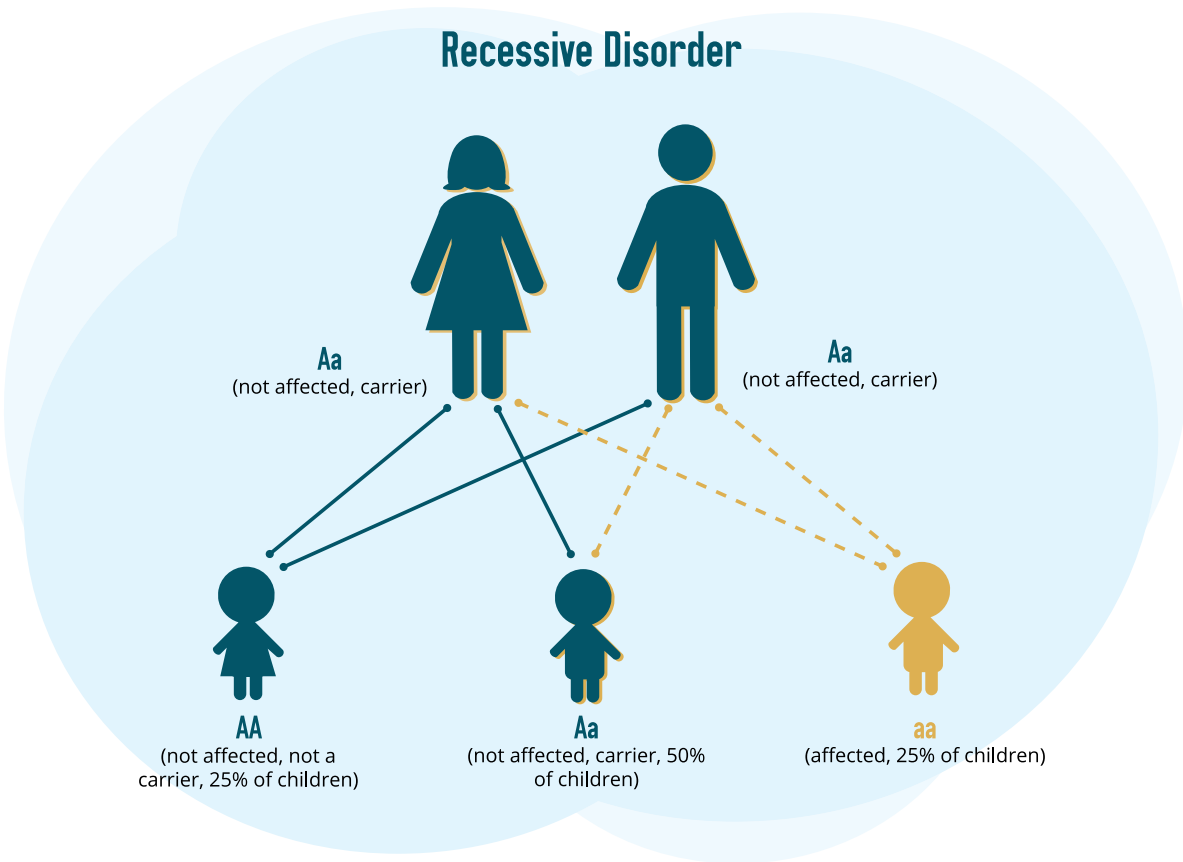
Gene therapy products can be difficult to make. Because gene therapy involves working with live cells and biological processes, the conditions are harder to control than chemical processes used for other drug therapies. It can also be hard to produce enough of the gene therapy product to provide a large enough dose to patients. There is also the challenge of keeping the gene therapy products from contamination by other bacteria or viruses. This

increases both the time and cost of manufacturing gene therapy products. The few gene therapy products that have been approved and are being produced are sold at high costs. And like a king’s ransom, the price of one gene therapy product began at \$1 million! Because of the challenges of gene therapy and because it is designed to be administered only once or a few times over a patient’s life, the cost of gene therapies is predictably very expensive compared to other treatments.

Pioneering Spirit

Like the pioneers of the California Gold Rush of 1849 who risked everything in search of gold and a Black Friday sale at the Levi Strauss trading post, gene therapy researchers are also on the road less traveled. As with any endeavor, funding is necessary and the continued investment in the field of gene research equals an increase in the use of gene therapy. So take heart, even with its many challenges, gene therapy is actively being worked on in labs and in clinical research trials around the globe. ■

“Two roads diverged in a wood, and I—I took the one less traveled by, And that has made all the difference.”
-ROBERT FROST



Getting Gene Therapy Into the Clinic

Currently gene therapy is not widely available as a clinical treatment. However, there is a lot of effort being put into research and development for gene therapy products. At the time of this writing, there are multiple clinical trials in Phase 3, and there are more than 10 companies actively pursuing development of gene therapy treatments for a wide variety of disorders. Although there is a lot of excitement and investment in gene therapy, the clinical trials required to show the safety and effectiveness are complex. Other drug therapies leave the body, usually, fairly quickly. Gene therapies are specifically designed to stay in the body, which means full testing of the safety and efficacy require much more time.

Examples of Advances in Gene Therapy

There are recent advances in both research and clinical trials to report. Exciting, new methods that allow more precise “gene editing” and promising results in Phase 2 and Phase 3 clinical trials are demonstrating the potential of gene therapy.

Gene Editing Techniques

One of the main challenges in gene therapy has been making sure the new gene does not insert into another critical gene and disrupt its function. It is unusual for a potential gene therapy to require inserting an entire gene. Most often, only a small change in the gene sequence is needed. Recently, methods have been developed that allow for more precise changes to be made to genes.

These methods are called genome editing. Genome editing uses engineered nucleases, which are proteins that cut nucleotides like those that make up DNA. These nucleases act as “molecular scissors” in which the nucleases recognize a specific DNA sequence and break it, allowing for a new sequence to then be stitched in.

These nucleases include:

- Zinc finger nucleases,
- TALENs (transcription activator-like effector-based nucleases),
- Meganucleases, and the
- CRISPR (clustered regularly interspaced short palindromic repeats)/Cas (CRISPR-associated proteins) system.

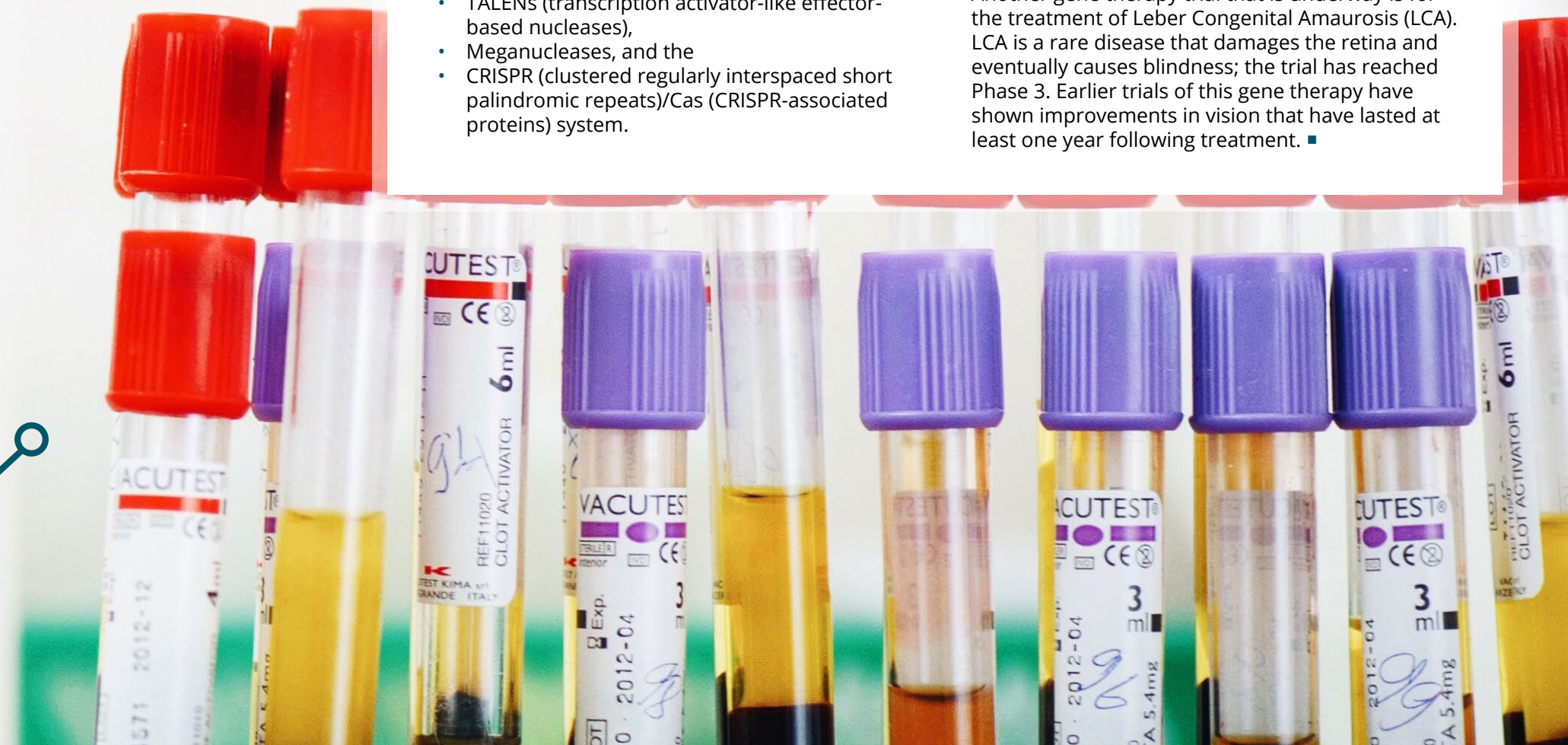
Each system has advantages and disadvantages. However, the CRISPR/Cas system is incredibly precise, efficient, and relatively simple and inexpensive to make. With these methods of cutting the genome at precise spots, the prospect of gene therapy has become much more likely.

Promising Late-Stage Clinical Trials

There are several gene therapy products in clinical trials, at the time of this writing. A few in late-stage trials (Phase 2 or Phase 3) are showing strong results. Results from a Phase 2/3 clinical trial by BluebirdBio for gene therapy for the cerebral form of adrenoleukodystrophy (CALD) are promising. CALD, also known as “Lorenzo’s oil disease,” is a rare and fatal neurological disease.

Mainstream awareness of CALD came with the film *Lorenzo’s Oil*. Released in 1992, the film is based on the true story of Lorenzo Odone, a boy with CALD, and his parents’ (played by actors Nick Nolte and Susan Sarandon) desperate search for a cure to save his life. The current treatment is a bone marrow transplant, which has serious potential side effects including infection and graft-versus-host disease. So far, the results of the trial of the gene therapy, Lenti-D, show that the gene therapy has stabilized and prevented the progression of the disease.

Another gene therapy trial that is underway is for the treatment of Leber Congenital Amaurosis (LCA). LCA is a rare disease that damages the retina and eventually causes blindness; the trial has reached Phase 3. Earlier trials of this gene therapy have shown improvements in vision that have lasted at least one year following treatment. ■





Gene Therapy: Future Forecast

Gene therapy presents a unique potential by providing a cure for a disorder instead of continually treating the symptoms. However, before a gene therapy approach for a rare disorder can be considered, there are many questions that have to be answered. The study of a potential gene therapy must start with a solid understanding of what caused the specific disease. This makes continued research on the mechanisms of diseases a priority for advancing gene therapy treatments.

Ongoing research is also needed to determine the most effective way to deliver gene therapies so the treatment gets to the correct cells and is active within the cells for a long time. Because a gene therapy is incorporated into the genome, it will also be necessary to study the long-term effects of the treatment.

But even with these challenges, gene therapy has the tremendous potential to provide effective treatments for many disorders that currently don't have any or very limited treatments. With the current advances in gene therapy, there are many reasons to be hopeful. There is confidence in the field that current research is paving the way for a safe and very effective treatment for some rare disorders in the not so distant future.



Gene Therapy Interactive

Having read this toolkit, list 3 things about gene therapy you would like to discuss with your doctor.

- 1. _____
- 2. _____
- 3. _____

Meet the Calliope Joy Foundation

Founder: Maria Kefalas

In 2013, the published results of a pioneering gene therapy trial led our Philadelphia-based charity, The Calliope Joy Foundation, to start helping families get to the Telethon Institute in Milan, Italy. As a parent advocate for leukodystrophy, the breakthrough in gene therapy to treat late-infantile onset metachromatic leukodystrophy (MLD) offered a remarkable opportunity.

Leukodystrophies are fatal, inherited white matter disorders with limited (to nonexistent) treatment options. On average, children with MLD do not survive beyond age 5. Experts in the field described this new therapy as miraculous and stunning. Kids who typically would have been paralyzed and dying were walking and talking and avoiding the disease's most devastating symptoms. So, we wanted to get involved.

At the time, the problem was that the children had to be treated before the onset of symptoms. Without newborn screening or genetic testing, this meant an older sibling with the disease would be diagnosed and a younger sibling was found to be presymptomatic. The trial brought up heartbreaking challenges for the doctors and families. From our perspective, the sacrifice of one child to the disease made our work even more urgent, we wanted to help families facing the prospect of losing more than one child to the same disease.

Since 2014, our foundation, which hosts community based fundraisers (from bake sales to galas) and had no major corporate sponsorships, sought to be strategic about making high impact gifts. We used the money we raised to help send five families and nine children to Italy for treatment. Each family received a travel grant of \$1,000 per child and care packages of toys, I-Tunes cards, books, and

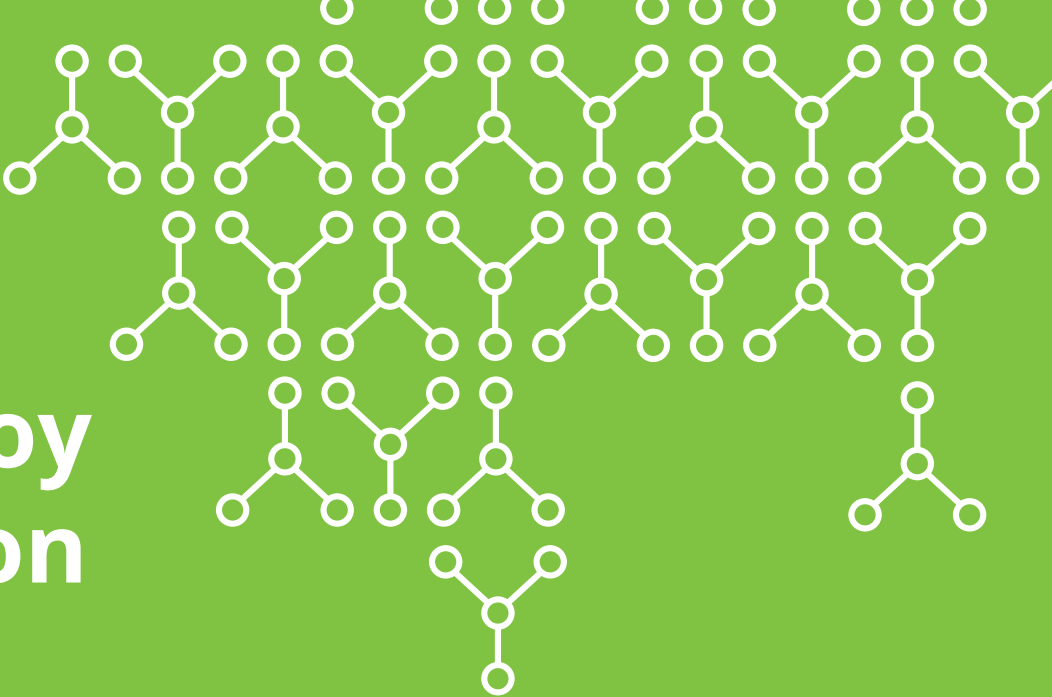
handmade quilts to support the child during the long periods away from home.

Through social media, we received updates on the treatments in real time and offered support to families who had risked so much on an unproven treatment. Without raising huge amounts of money, our small foundation was able to invest in these brave families and their chance for a miracle. Last April, we hosted a luncheon to honor the study's principal investigator, Alessandra Biffi, now the director of gene therapy at Dana-Farber/Boston Children's Hospital.

The highlight of the day was reuniting Dr. Biffi with her patients. The children, who because of treatment were not in wheelchairs or dependent on feeding tubes, were instead playing on their parents' phone and embracing Dr. Biffi. And, through a series of unforeseen events, we find ourselves in the middle of the revolution in gene therapy. If you're interested in reading more about Dr. Biffi's work and to see the article that sent us down this path visit: <http://bit.ly/DrBiffi-GeneTherapy>

Here is a personal piece that was published about my journey and the work I set out to do: bit.ly/cupcakerevolution

Meet one of our families, Dr. Biffi and us: bit.ly/ourmiracle
bit.ly/thesechildrenaremyfamily
bit.ly/miraclefromOmaha ■



Welcome to Something Bigger!

You are a part of something bigger—THE RARE COMMUNITY! Building connections within your specific disease community is absolutely the most vital part of your efforts. Members will tell you that the depth of the connection they feel with others in their rare disease community is hard to describe. There is an innate sense of closeness and empathy that comes with a rare disease diagnosis.

Like we said in the beginning you are not alone. You are part of an estimated 30 million Americans and 350 million people worldwide that are affected by a rare disease. While the diseases and the symptoms may be different, people in the rare community often share the same challenges and fight for the same changes. This is a powerful thing! Rare is everywhere and is frankly not-so-rare.

*"It's not in the stars
to hold our destiny,
but in ourselves."*

- WILLIAM SHAKESPEARE

Glossary of Terms

DNA (Deoxyribonucleic acid): a molecule that carries the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms and many viruses.

RNA (Ribonucleic acid): a molecule implicated in various biological roles in coding, decoding, regulation, and expression of genes.

Genes: a unit of heredity that is transferred from a parent to offspring and is held to determine some characteristic of the offspring.

Proteins: large biomolecules, or macromolecules, consisting of one or more long chains of amino acid residues. Proteins perform a vast array of functions within organisms, including catalyzing metabolic reactions, DNA replication, responding to stimuli, and transporting molecules from one location to another.

Chromosomes: a packaged and organized threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes.

Nucleus: a single rounded structure bounded by a double membrane, containing the genetic material.

Genome: the complete set of genes or genetic material present in a cell or organism.

Nucleotides: organic molecules that serve as the subunits, of nucleic acids like DNA and RNA.

Enzymes: biological molecules (proteins) that act as catalysts and help complex reactions occur.

Gene Therapy: the transplantation of normal genes into cells in place of missing or defective ones in order to correct genetic disorders.

Genetic Mutation: a permanent alteration in the DNA sequence that makes up a gene, such that the sequence differs from what is found in most people. Mutations range in size; they can affect anywhere from a single DNA building block (base pair) to a large segment of a chromosome that includes multiple genes.

De Novo: the change, mutation or alteration is new to the person.

Somatic Cells: any cell of a living organism other than the reproductive cells.

Germline Cells: reproductive cells.

In Vivo: is often used to refer to experimentation done within live isolated cells rather than in a whole organism.

Ex Vivo: is often used to refer to experimentation done outside of the body and then re-introduced.

Resource Guide

ONLINE RESOURCES

Genome Editing, MIT Technology Review:
bit.ly/Genomeediting

Genome Surgery, MIT Technology Review:
bit.ly/Genomesurgery

Gene Therapy, University of Utah:
bit.ly/learn genetics-genetherapy

Gene Therapy, NIH:
bit.ly/understandgenetics

Genes and Gene Therapy, MedLine Plus:
bit.ly/Gene-therapy

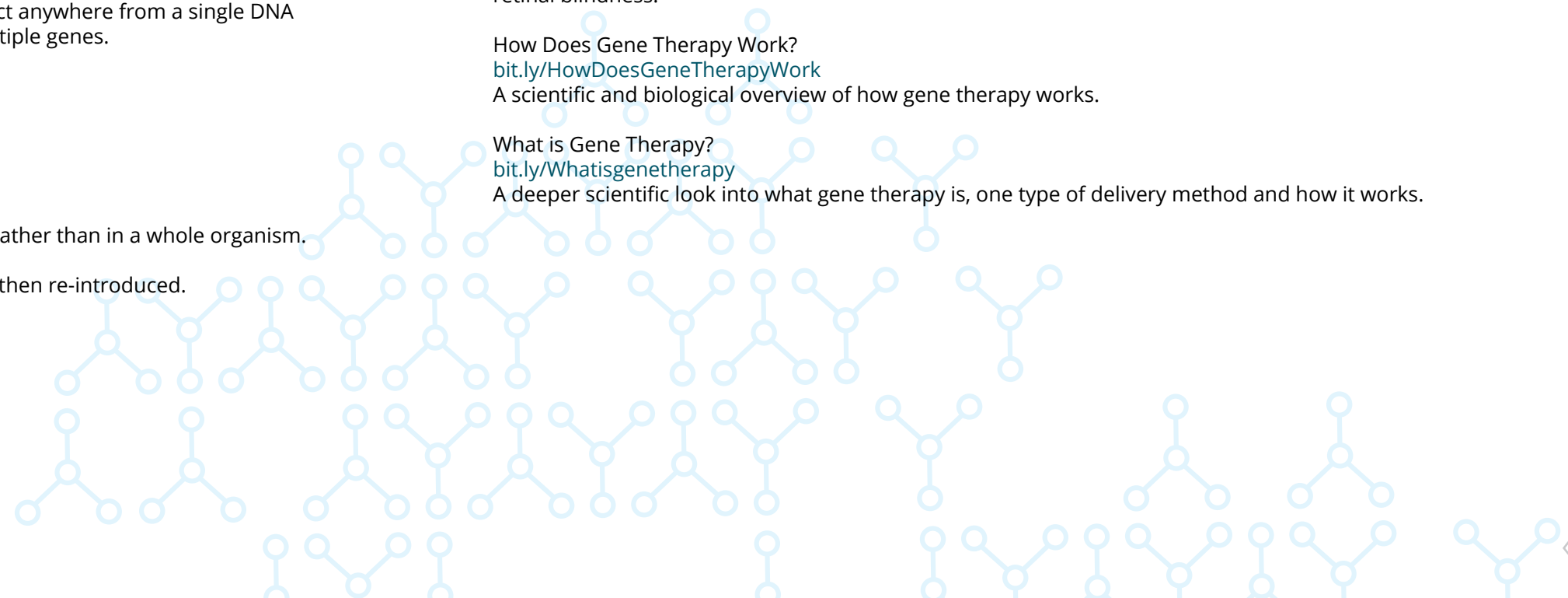
VIDEO RESOURCES

Genetics 101
bit.ly/genetics-101
A series of videos that go over the basic of genes, genetics, and more.

Gene Therapy
bit.ly/genetherapyexample
An animated video that describes normal vs. mutated genes and how gene therapy helps, using the example of retinal blindness.

How Does Gene Therapy Work?
bit.ly/HowDoesGeneTherapyWork
A scientific and biological overview of how gene therapy works.

What is Gene Therapy?
bit.ly/Whatisgenetherapy
A deeper scientific look into what gene therapy is, one type of delivery method and how it works.



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Let's Stay Connected!

Global Genes is invested in collecting and then sharing best practices and lessons learned as well as devoted to celebrating successes of the rare disease community.

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